The Thesis Committee for James Joseph Corboy
Certifies that this is the approved version of the following Thesis:

Improving Energy Literacy with Online/Video Resources: The Switch Curriculum Example

APPROVED BY
SUPERVISING COMMITTEE:

Scott Tinker, Supervisor

Jill Marshall

Christopher Bell

Improving Energy Literacy with Online/Video Resources: The Switch Curriculum Example

by

James Joseph Corboy

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Dedication

To my gorgeous and amazing fiancé, Terri Sjodin, who motivated, inspired, and supported me throughout this process.

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Abstract

Improving Energy Literacy with Online/Video Resources: The Switch Curriculum Example

James Joseph Corboy, GEOSCIMS

The University of Texas at Austin, 2019

Supervisor: Scott Tinker

In response to years of American students demonstrating poor understanding of energy and energy-related issues, a number of groups have sought to improve student energy literacy by developing curriculum that engages and motivates students to learn more about this important subject. Although the energy documentary film *Switch* was not produced with a classroom experience in mind, the success of the film in connecting with environmentalists, industry, and academia supported using the documentary to test the power of film as an effective teaching tool for improving energy literacy. To test the effectiveness of *Switch*, we created an assessment tool to first determine students' baseline energy literacy, and then determine whether the documentary effected a change.

This assessment indicated that many incoming college students identify their Advanced Placement Environmental Science class as the place they learned about energy. The assessment results indicate that students' attitude, behavior, and knowledge about energy and energy-related issues changed in a statistically significant way over the course

of a 2-3 day learning experience. The effect size increase of 0.47 on energy knowledge supports using the documentary *Switch*, and similar non-partisan films designed for objective education, as inexpensive, scalable teaching tools to introduce energy in the classroom.

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Chapter One: Switch Energy Alliance: Improving the Energy Conversation

The foundation of world economic growth since the industrial revolution has been affordable and reliable energy (Chu and Majumdar, 2012). Meeting future energy demand with sustainable resources, while improving prosperity, challenges developed and developing economies with a complex, technical, economic, and political problem. Successfully addressing the ongoing energy transition requires sound policy decisions, and just as importantly, a well-informed citizenry on energy-related topics and issues (NEETF, 2002; NEF, 2018).

Unfortunately, research indicates the public lacks basic energy literacy. A recent National Energy Foundation (NEF) assessment of 2,000 high school students and recent graduates resulted in an average group score below fifty percent. Only twenty-seven percent answered this question correctly: Which three resources provided 86% of the electricity generated in the U.S. in 2015? (NEF, 2018). The answer is coal, natural gas and nuclear. The *Switch* Energy Alliance (SEA) aims to engage students and the public, through film, to create an energy literate populace equipped to make responsible future energy decisions.

Film and video provide a powerful teaching tool to open minds, enhance our understanding, and inspire us to make a difference. In 2009, Texas Emmy-award winning filmmaker Harry Lynch and Texas State Geologist and Professor Dr. Scott Tinker collaborated to create the documentary *Switch*. *Switch* examined global energy

resources, the scale of energy system infrastructure, economics, and technology. Best of fest at the Colorado Environmental Festival and opening night selection for the Environmental Film Festival in D.C, *Switch* has been seen by over 15 million viewers in 50 countries. It engaged environmental and energy scientists, the energy industry, and the general public in discussion about the best path toward a sustainable energy future.

SEA History and Education Platform

Motivated by the success of *Switch* and the desire to improve the energy conversation, Tinker and Lynch expanded the educational content with the *Switch* Energy Project, whose website offered accessible, engaging, non-partisan, fact-based content via labs, primers, site visits and expert interviews. The objective was to advance an understanding of the importance of energy using innovative, entertaining, educational videos. Five years later, the team reconvened and formed the 501(c)(3) *Switch* Energy Alliance (SEA) to address global energy poverty via a new film, *Switch* On, and significantly expanded content and reach.

Although a number of organizations work to improve energy literacy, including the Department of Energy, Canadian Energy Literacy Network, National Energy Education Development (NEED) Project, and the National Energy Foundation (NEF), SEA is the only energy education non-profit to create feature-length documentary films on energy. SEA content focuses on energy resources using short, captivating videos directed to middle school, high school, and college undergraduate students. SEA has

partnered with NEED and the NEF recognized SEA online videos as a way to connect and motivate students to learn about energy-related topics (NEF, 2018).

Our powerful new website (https://switchon.org/) makes film and video a more effective teaching tool by creating robust, interactive modules (Figure 1-1) and a customized user experience. The dashboard includes colorful visual aids to graphically track cumulative learning. Viewers' interests lead to unique video recommendations. Soon, educators will be able to create individualized lessons, administer students, and organize videos and activities to monitor student progress and offer and grade quizzes.

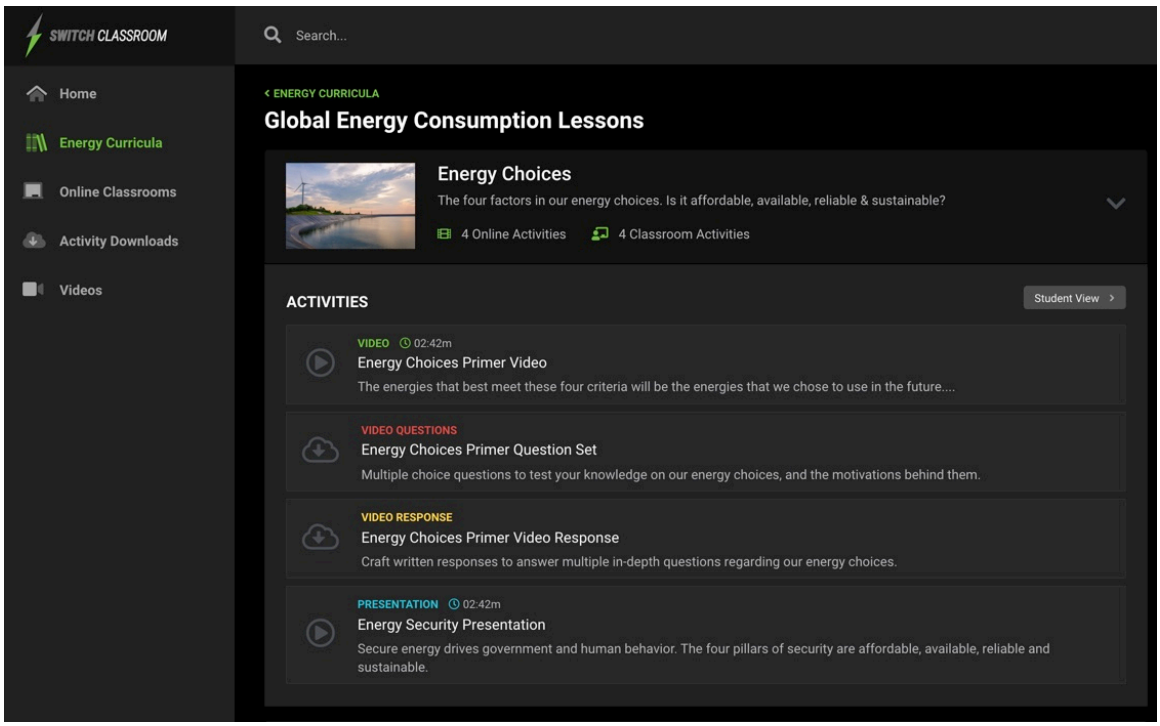

Figure 1-1: Energy Concepts-Learning Module (https://switchon.org/teacher/module/module-energy-concepts)

The *Switch* Energy Lab series provides experiential teaching tools to engage and strengthen energy knowledge. Dr. Tinker conducts experiments and fieldwork with often surprising and unexpected results. Each of the 28 short videos was designed for viewers

of all levels and ends with a summary. These labs are fun, informative and include pros and cons of each major energy resource. Rachel Batron of Louis Maslow STEM School in Wyoming writes, "…the video clips are easy to use and very helpful to illuminate the realities of our current energy use and suggestions for the future." Advanced Placement Environmental Science (APES) teacher Chris Mihealsick from Austin, Texas uses the videos in class and then asks students to identify three main points of the clips, followed by instruction to elaborate on the topic.

The *Switch* Energy Primers present benefits and challenges of every major energy resource, and issues driving supply and demand in the world's leading economies. The primers consider topics such as scale, efficiency, and environmental impact. For example, the "Foundation of Modern Life" examines how households, industry, and government consume energy 24 hours a day. According to SEA website analytics, 19% of activity in 2018 was teachers showing the energy primers in class.

Interviews with a wide range of energy experts are a key and expanding part of the site. Dr. Dan Sperling, UC Davis Institute of Transportation Studies Director, discusses biofuels, hydrogen, hybrids, and electric cars. Dr. Larry Walker, Cornell Biofuels Lab Director, considers next generation cellulosic biofuels and their potential role in transportation fuels. Dr. Sally Benson, Stanford University Energy Program Director, explores carbon capture, renewable energies, and the challenges for their deployment and adoption. This is just a sampling of some 25 energy experts who deliver a broad range of views about the world's energy scene.

In 2018, SEA began assessing the effectiveness of *Switch* to teach energy literacy. We developed an assessment tool (Appendix A; https://utexas.qualtrics.com/jfe/form/SV_2n2mXRsNTQxaGzz) to gauge students' attitudes toward energy, behavior with respect to energy and use, and knowledge of energy. After watching *Switch*, students take a post-assessment using the same set of questions. Early data show growth from 8-20% on the energy knowledge section and improvement of student attitudes about energy.

SEA asked over 10,000 newsletter subscribers how they use our materials in their classrooms (Appendix B; https://utexas.qualtrics.com/jfe/form/SV_dp4J0T0JTKGGezP). Educators use the feature film (36%) as an introduction, and the energy labs and primers (33%) to focus on specific resources. Students typically are assigned questions to answer, three main points to identify, or a short summary to write following a video. "I stream *Switch* curriculum materials into my Energy Resources class to help my students understand the economic, environmental, and social ramifications of all energy resources,'' states Theodore Erski of McHenry County College.

Educators using SEA materials include 40% university, 40% high school, 13% middle school, and 7% elementary school. Eighty-eight percent of respondents identified our content as very useful to extremely useful. Some suggested improvements, including teacher guides, lesson plans, questions to accompany videos, and activities/homework. Currently, we are focused on curriculum development for the APES energy resource and consumption unit. SEA is on the forefront of digital and film-based educational

resources, and a "flipped classroom" model in which students watch films and answer questions outside the classroom before teachers lead discussions in class.

We have formed a teacher advisory council (TAC) made up of APES teachers, college professors, and energy experts to help develop curriculum and test online tools. The TAC has begun meeting and developing curriculum to go along with each of our energy lab and primer videos. Our education goal is turnkey learning modules for the APES energy unit including questions, lessons, pre- and post-assessments, and hands-on activities.

Switch Energy Clubs

SEA is assisting universities and high schools to launch interdisciplinary energy clubs where students learn about energy, develop leadership and communication skills, network with energy professionals, and engage in civil discussions. We provide each chapter with startup resources to form and operate a club. Club members gain access to SEA's vast video library, PowerPoint slides, and presentations about energy. SEA and club sponsors utilize their contacts to find speakers, host energy-related competitions, and plan field trips.

Switch On: A Documentary Film on Energy Poverty

Energy is the star of the film *Switch*, but we neglected one of the world's great challenges: energy poverty. *Switch* On seeks to understand best practices to provide electricity to 1/7 of the world's population (1 billion people) and clean cooking to some

2.7 billion who cook over wood and coal inside their homes. As part of the film, we installed a 3.5 kW solar micro-grid in an indigenous village in northeast Colombia, South America. The project provides a case-study to address rural energy poverty with distributed solar. We are also examining centralized grid solutions to urban energy poverty, and clean cooking strategies in countries such as Nepal, Ethiopia and Kenya.

Join the Conversation

We believe that access to affordable and available energy resources is a vital part of the solution in developing, emerging, and undeveloped nations. Energy can help improve literacy, reduce negative health effects, advance the status of women, erode corruption, slow birth rates, and create circumstances for freedom. In developed nations, a focus on improving environmental impacts of energy—local and atmospheric emissions, land use and land fill, water use—and more efficient use of energy through awareness are paramount. We encourage scientists, educators, and students to join us in this important conversation.

Chapter Two: Improving Energy Literacy with Online/Video Resources: The *Switch* Curriculum Example

Introduction

Energy is ubiquitous in the modern economy and low-cost energy remains a critical component for continued economic growth and increased prosperity. Future energy demand could strain world resources and the environment, and meeting demand sustainably will require a more energy-literate population. The U.S. Energy Information Administration (EIA) predicts that world energy consumption will grow by 28% between 2015 and 2040 (EIA, 2019) and global demand even more so. However, surveys since the energy crisis of 1973 have consistently shown Americans' energy IQ to be poor (low) (Holmes, 1978; NEETF, 2002; DeWaters and Powers, 2011).

Film is a powerful educational tool with the potential to open minds (Franks, 2013), motivate students to learn more about science and the scientific method (Laursen and Brickley, 2011; Wiggen and McDonnell, 2017), think critically (Hopper, 2011; Tinker, 2019), view multiple perspectives (Hess, 2007), and build a bridge to better understanding of controversial societal challenges of the 21st century such as water, energy, and climate (Stoddard, 2009; Marcus and Stoddard, 2009).

At Switch Energy Alliance (SEA), our subscribers have been using our film *Switch* (https://switchon.org/films/), the *Switch* Energy Labs, our primers, and other short format videos (https://switchon.org/teacher/) in multiple discipline classes at over 1,000 universities and K-12 campuses around the world to teach and inspire students to learn

about energy. SEA strives to prepare students with fundamental energy and energy-related knowledge so that as future citizens they can make informed decisions.

To evaluate the effectiveness of the documentary *Switch* as a teaching tool to improve energy literacy, we created an assessment to measure students' baseline energy IQ before watching the film, then assessed student growth after watching *Switch* without requiring any ancillary online or in-class activities.

Literature Review

Energy literacy defined by the Department of Energy is "an understanding of the nature and role of energy in the world and daily lives accompanied by the ability to apply this understanding to answer questions and solve problems" (DoE, 2015). This term embodies basic energy knowledge, attitude with respect to energy, and behavior concerning energy. Knowledge of energy is only one part of recent energy literacy studies, and we strive for energy literacy that motivates and inspires not only knowledge, but a change in attitude and individual energy behavior (DeWaters and Powers, 2007; NEF, 2018).

In 1978, Barbara Holmes published a national evaluation of energy literacy among 1,300 young adults between the ages of 18 to 25 across the United States (Holmes, 1978). Her study involved energy knowledge and attitude questions. Only 14% of the participants knew which resource produced the largest portion of the United States' electrical energy (Answer: Coal). The National Environmental Education &

Training Foundation (NEETF, 2002) assessment of 1,503 Americans, age 18 or older, showed similar results with only 12% of the participants passing the basic energy quiz.

A recent energy literacy survey by DeWaters and Powers (2011) evaluated the energy knowledge, affect, and behavior of 3,708 secondary students in New York, USA, and found discouragingly low energy cognitive scores with a mean of 40% for middle school and 44% for high school students. Only one-third of the participants chose energy conservation as the fastest and most effective way to address energy demand, similar to results in the 2002 NEETF study where 39% chose energy conservation on a similar question, and only 14% of students knew that coal produced the majority of our electricity at that time. As a side note, in recent years, hydraulic fracturing combined with horizontal drilling in shale has made natural gas in the United States cheap and reliable, and it has replaced coal as the dominant fuel for power generation, emphasizing the need for ongoing and current energy education. These examples demonstrate America's ineffective energy education over more than 30 years.

In 2018, the National Energy Foundation (NEF) completed the most recent energy literacy assessment with over 2,000 high school seniors and recent graduates. NEF administered their survey to a demographically-diverse group, and the average knowledge score was 48.8% with a normal distribution. The NEF white paper recommended a variety of ways to improve energy education, including online videos from the *Switch* Energy Alliance, in order to create more student engagement.

Purpose

Our study uses an energy literacy assessment tool created in Qualtrics to identify student baseline energy knowledge, attitude, and behavior. Then students watch the objective documentary, *Switch,* to learn about the main sources of energy and how a number of countries have made their energy transition from dominantly coal to an increased utilization of natural gas, nuclear and renewable energy to meet their energy demand. Afterward students take the same assessment to determine whether watching *Switch* changed their energy attitude, behavior, or knowledge. This study, in contrast to previous work, uses a pre- and post-methodology with an intervention centered on *Switch* to gauge whether we can achieve a more energy-literate student population using film as a teaching tool.

Method: Procedure

We began this study by applying for and receiving approval from the University of Texas Institutional Review Board (#2018-0700118), which involved a waiver of signed content for students who participated anonymously in the research. The IRB stated the study's purpose was to explore using a film as a teaching tool to improve energy literacy, and whether the pre/post assessments accurately assessed student learning.

Our research team invited faculty at the University of Texas to participate in our study and a pilot sample of 41 students completed the initial assessments. To broaden the sample, we developed an online teacher survey using Qualtrics (Appendix B;

https://utexas.qualtrics.com/jfe/form/SV_dp4J0T0JTKGGezP) and emailed this link to SEA educator newsletter subscribers and any educator who had requested the *Switch* DVD using the email service MailChimp. The MailChimp data shows 2,197 (22.8%) of the recipients opened the email, 272 (2.8%) educators clicked on the survey, and 105 educators completed the survey. In the survey we asked educators, "Would you be interested in using our assessment tools along with the *Switch* film to evaluate the effect of our film on student energy literacy learning?" Eighty-three teachers (79%) responded that they were interested in participating in our study, expanding our participant base.

Teachers who showed interest in participating in the study were sent a unique link to the *Switch* Energy Alliance Energy assessment tool (Appendix A; https://utexas.qualtrics.com/jfe/form/SV_2n2mXRsNTQxaGzz) for their classes with directions for student participation. The pre-assessment contained a short introduction informing participants of the research study, indicating that continuing with the survey was voluntary and constituted consent for their responses to be analyzed. Directions told students to click on the unique link and complete the pre-assessment; when finished, students were asked to copy the link for the post-assessment. By copying the link, they created a random ID which allowed us to match pre- and post-results, while maintaining anonymity. Next, students watched *Switch* (https://switchon.org/films/). After watching the documentary, students completed the post-assessment. To access the assessment, students used their unique link with an embedded random ID and then signed into the post-assessment by typing in a password.

Assessment Tool

The assessment tool (Appendix A: *Switch* Energy Alliance Energy Literacy Assessment; https://utexas.qualtrics.com/jfe/form/SV_2n2mXRsNTQxaGzz) consisted of five sections: attitude about energy, behavior with respect to energy, knowledge of energy, what contributed the most to student understanding of energy, and what percentage of electricity in the United States is generated by each fuel source.

The attitude assessment section looked at student beliefs or opinions about energy. It included 15 statements that used a 5-point Likert scale with student responses ranging from strongly agree (5 points) to strongly disagree (1 point). This section looked at student beliefs or opinions about energy. For example, "I have an above-average knowledge about energy production, consumption, and conservation."

The behavior assessment section included 9 items, ranging from always (5 points) to never (1 point) that looked at individual behavior with respect to energy. For example, "I will walk or bike short distances, instead of driving a car."

The knowledge assessment section included 22 multiple-choice knowledge questions that were scored as correct (1) or incorrect (0). The knowledge questions fell under three broad categories: basic energy facts, energy conservation and consumption, and energy resources. An example of a basic energy fact was, "An incandescent light bulb converts 10% of the energy into light and 90% into which form of energy?" On energy consumption, an example was, "Which sector of the United States consumes the most energy?" An energy resource question, for example, asked "Which energy source supplies the majority of transportation fuels?"

Section four looked at what contributed the most to student understanding of energy, including whether a film on energy had impacted their attitude or behavior.

Section five asked students to predict the percentage of electricity generated in the United States by each energy resource including hydropower, natural gas, nuclear, oil, coal, renewables, and others.

Intervention

The energy documentary *Switch* was created in 2013 by Professor and Texas Bureau of Economic Geology Director Dr. Scott Tinker and documentary filmmaker Harry Lynch. Combining their two passions, they created a nonpartisan, objective documentary embraced by energy industry, environmentalists, and academia. A review of *Switch* by Variety states, "Sidestepping the usual eco-docu strategy, *Switch* takes a far less hysterical route. Lynch's method gives a rational evaluation of the world. It's considerably more honest, and manages to be quite effective." While Forbes wrote "Switch offers a scientific look at how we use energy." The film has reached more than 15 million viewers, been included in over 2,000 global universities' curriculum, and been integrated into K-12 energy education including the energy unit for the Advanced Placement Environmental Science (APES) course.

As a documentary film, *Switch* played in three acts: foundational energies of coal and oil, transportation options, and electricity options. The film's 14 scenes begin with Norway and making the energy transition, and include coal, oil, powering growing nations, biofuels, natural gas for transportation, unconventional oils, electric cars,

geothermal, solar, wind, natural gas for electricity, nuclear, and the value of efficiency. The full-length documentary is available free online in its entirety (https://switchon.org/watch/video/switch-the-complete-film) or it can be viewed by chapters (https://switchon.org/watch/video/switch-chapter-1). The length of the film is approximately one hour and 38 minutes.

Measure

When all students finished the assessment, we exported the results into an SPSS statistical software system. In SPSS, we first looked at the Cronbach's alpha for the attitude and behavior parts of the survey to determine if the tool was internally consistent. Next, we ran a factor analysis on students' attitude and behavior to find if there were recognizable patterns to how students answered these items.

To analyze pre- and post-results and differences between genders, we calculated composite means for the attitude, behavior, and knowledge. The sample included only the results from 264 high school and 125 university students (N=389) whose random ID's connected their pre- and post- assessments.

First, to test gender neutrality, we executed an independent sample t-test to determine if there is a statistically significant difference between genders. DeWaters and Powers (2011) found that the only male/female differences were in the attitude section of their survey. Previous studies demonstrate females have a propensity for greater positive attitude toward energy issues than males (Lawrenz and Dantchik, 1985; Barrow and Morrisey, 1987; Agarwal, 2000), and acknowledge the importance of individual effort

and energy conservation (Kuhn, 1979). Next, using the paired sample t-test, we evaluated whether *Switch* effected student energy literacy: attitude about energy, behavior with respect to energy, and energy knowledge. Lastly, we utilized the mean, standard deviation, and sample number from the paired sample t-test to calculate Cohen's d, which determined the effect size of the film on attitude, behavior, and knowledge.

Results

Participants in the research included high school and university students ranging in age from 14 to 67 years old with their high school education spanning 30 different states. The pre-assessment had 1062 participants, while the post-assessment had 636 participants. However, owing to the testing approach and challenge some students had with following directions, only 264 high school and 125 university students (N=389) had a random ID allowing us to link pre and post-assessments.

The reliability test and Cronbach's alpha indicate an internally consistent assessment of student attitude and behavior toward energy (Table 2-1). Cronbach's alpha for the Attitude section was improved by dropping questions 6 and 7 from the assessment tool: the criteria we are using for internal reliability is > 0.7. The Cronbach's alpha for the pre-Behavior data was 0.678, which is slightly less than 0.7 criterion. After the film the post-Behavior results showed a Cronbach's alpha of 0.735. The data suggest that the assessment tool is internally reliable for attitude and behavior.

Internal Consistency				
Assessment	**# of Items**	**# of samples**	**% Valid**	**Cronbach's Alpha**
Pre-Attitude	13	1062	90.8	**0.788**
Post-Attitude	13	636	98.1	**0.771**
Pre-Behavior	9	1062	97.5	**0.678**
Post-Behavior	9	636	98.4	**0.735**

Table 2-1: Reliability Test

An exploratory factor analysis (EFA) on attitude using a Varimax rotation separated the 13 attitude items into three distinct components with strikingly similar loading for the pre- and post-attitude assessments (Table 2-2A, 2-2B, and 2-2C). The first component (Table 2-2A) mainly connects students' belief that government has a role to play in education, regulation, and promoting solutions to energy efficiency and energy conservation. The second component (Table 2-2B) connects items that revolve around the idea that renewable energy and new technology are important to students. The third component (Table 2-2C) links the view that fossil fuels and nuclear are bad. The fact that the pre- and post- factor loading of these items are the same and the loading is similar implies that it is a very reliable factor analysis.

Component 1	1-Pre	1-Post
I have an above-average knowledge about energy production, consumption, and conservation (1).	0.416	0.414
Energy conservation and efficiency should be a part of a balanced education (2).	0.757	0.757
Governments should develop standards for gas mileage of cars and efficiency of appliances [refrigerators, dryers] (9).	0.674	0.734
All electrical appliances should have a label that shows the resources used in making them, their energy requirements, and average operating costs (10).	0.733	0.761
Present day climate change is caused by human activity (12).	0.637	0.744
Renewable forms of energy are good (13).	0.520	0.539

Table 2-2A: Attitude Factor Analysis-Component 1

Component 2	2-Pre	2-Post
New technology will solve our future energy problems (3).	0.459	0.673
Addressing climate change is more important than addressing global poverty (4).	0.530	0.433
We should develop renewable energy, regardless of economic and environmental costs (5).	0.750	0.717
The fastest way to address climate change is to convert from fossil fuels to renewable energy (8).	0.610	0.634
More wind farms should be built to generate electricity, even if they are located in scenic valleys or hills, farm or ranch lands, lakes or oceans (11).	0.568	0.445

Table 2-2B: Attitude Factor Analysis-Component 2

Component 3	3-Pre	3-Post
Fossil fuels are bad (14).	0.705	0.706
Nuclear power is bad (15).	0.799	0.793

Table 2-2C: Attitude Factor Analysis-Component 3

After running the factor analysis, we reduced the sample number to only students whose pre-and post-assessments linked with their random ID's and measured the mean for attitude, behavior, and knowledge using SPSS Statistics compute mean. We took this smaller sample size and the composite means for attitude, behavior, and knowledge to

perform an independent sample t-test, paired sample t-test, and for calculating the effect size.

We performed an independent sample t-test to determine whether there is a statistically significant difference between genders (Tables 2-3A, 2-3B, and 2-3C). To determine statistically significance, we used the accepted criterion of < 0.05. There was not a significant statistical difference between genders for the pre-attitude (0.09), but there is a difference in attitude between genders after the intervention (0.00). The male mean average for pre-attitude (3.60) and post-attitude (3.73) were slightly higher than for females, respectively (Table 3A). The attitude statements were evaluated using strongly agree (5) to strongly disagree (1).

Pre-Attitude

Group Statistics				
Gender	N	Mean	Std. Deviation	Std. Error Mean
Male	168	3.60	0.502	0.039
Female	221	3.52	0.380	0.026

	Levene's Test for Equality of Variances		t-test for Equality of Means		
	F	Sig.	t	df	Sig. (2-tailed)
Equal variances assumed	4.601	0.033	1.698	387	0.09036

Post-Attitude

Group Statistics				
Gender	N	Mean	Std. Deviation	Std. Error Mean
Male	169	3.73	0.426	0.033
Female	220	3.58	0.348	0.023

	Levene's Test for Equality of Variances		t-test for Equality of Means		
	F	Sig.	t	df	Sig. (2-tailed)
Equal variances assumed	7.059	0.008	3.754	387	0.00020

Table 2-3A: Independent Sample T-Test-Attitude

Males on average more strongly agree with these two attitude statements:

Q5-6: My personal use of energy does not make a difference in the grand scheme of things;

Q5-7: I don't worry about turning off lights or computers in the classroom because the school pays for the electricity.

Female students on average agreed more with these 3 statements:

Q5-10: All electrical appliances should have a label that shows the resources used in making them, their energy requirements, and average operating costs;

Q5-9: Governments should develop standards for gas mileage of cars and efficiency of appliances [refrigerators, dryers];

Q5-15: Nuclear power is bad.

While males' average mean responses for attitude were slightly higher than responses from females, the exact opposite occurred with the behavior statements (Table 3B.). The female average mean for the behavior statements before the film was 3.39 (males=3.27), while after the film females averaged 3.48 (males=3.37). However, only in the pre-behavior responses was there a statistically significant difference between genders ($\rho = 0.045$). Scoring for behavior statements ranged from always (5) to never (1). Two behavior statements that stood out in the data for females:

Q6-3: I turn off lights when leaving a room

Q6-1: I make effort to save water

The only behavior statement that males significantly differed from females was:

Q6-7: I drive an energy efficient car, where males were statistically higher than females in the affirmative.

Pre-Behavior

Group Statistics				
Gender	N	Mean	Std. Deviation	Std. Error Mean
Male	168	3.27	0.568	0.044
Female	221	3.39	0.562	0.038

	Levene's Test for Equality of Variances		t-test for Equality of Means		
	F	Sig.	t	df	Sig. (2-tailed)
Equal variances assumed	0.099	0.754	-2.007	387	0.04541

Post-Behavior

Group Statistics				
Gender	N	Mean	Std. Deviation	Std. Error Mean
Male	169	3.37	0.643	0.049
Female	219	3.48	0.627	0.042

	Levene's Test for Equality of Variances		t-test for Equality of Means		
	F	Sig.	t	df	Sig. (2-tailed)
Equal variances assumed	0.093	0.760	-1.602	386	0.10994

Table 2-3B: Independent Sample T-Test-Behavior

The knowledge responses did not show any significant statistical difference for either pre- or post-knowledge results. Males average mean scoring for the pre-knowledge assessment was 0.63, while females average 0.62. The post-knowledge results males and females average mean was the exact same 0.70.

Pre-Knowledge

Group Statistics				
Gender	N	Mean	Std. Deviation	Std. Error Mean
Male	168	0.63	0.175	0.014
Female	221	0.62	0.142	0.010

	Levene's Test for Equality of Variances		t-test for Equality of Means		
	F	Sig.	t	df	Sig. (2-tailed)
Equal variances assumed	11.811	0.001	0.350	387	0.72621

Post-Knowledge

Group Statistics				
Gender	N	Mean	Std. Deviation	Std. Error Mean
Male	169	0.70	0.184	0.014
Female	220	0.70	0.159	0.011

	Levene's Test for Equality of Variances		t-test for Equality of Means		
	F	Sig.	t	df	Sig. (2-tailed)
Equal variances assumed	3.014	0.083	0.087	387	0.93089

Table 2-3C: Independent Sample T-Test-Knowledge

To determine whether there were significant statistical differences between the pre- assessment results and the post-assessment results, a paired sample t-test was performed using SPSS Statistics. The paired sample t-test showed statistically significant change from the intervention (Table 2-4A, 2-4B, and 2-4C) for attitude, behavior, and knowledge. The change in attitude and knowledge was more statistically significant than behavior, but the data suggests the film had an impact on students.

Attitude

Paired Samples Statistics				
	N	Mean	Std. Deviation	Std. Error
Pre-Attitude	389	3.55	0.438	0.022
Post-Attitude	389	3.65	0.390	0.020

Paired Differences						
Assessment	Mean	Std. Deviation	Std. Error	t	df	Sig. (2-tailed)
Pre-Attitude-Post-Attitude	-0.094	0.371	0.019	-5.003	388	0.00000

Table 2-4A: Paired Sample T-Test-Attitude

Behavior

Paired Samples Statistics				
	N	Mean	Std. Deviation	Std. Error
Pre-Behavior	388	3.34	0.566	0.029
Post-Behavior	388	3.43	0.635	0.032

Paired Differences						
	Mean	Std. Deviation	Std. Error	t	df	Sig. (2-tailed)
Pre-Behavior-Post-Behavior	-0.093	0.458	0.023	-4.014	387	0.00007

Table 2-4B: Paired Sample T-Test-Behavior

Knowledge

Paired Samples Statistics				
	N	Mean	Std. Deviation	Std. Error
Pre-knowledge	389	0.62	0.157	0.008
Post-Knowledge	389	0.70	0.170	0.009

Paired Differences						
	Mean	Std. Deviation	Std. Error	t	df	Sig. (2-tailed)
Pre-knowledge-Post-Knowledge	-0.072	0.153	0.008	-0.056	388	0.00000

Table 2-4C: Paired Sample T-Test (Knowledge)

Students' attitude about energy went from 3.55 to 3.65 mean average after watching *Switch*, which shows that viewing the film had a small effect. The results for behavior had a slightly less effect as student's started at a mean score of 3.34 and their post results were 3.43. Knowledge questions were scored with a either a 1 correct or 0 when it was incorrect. The average mean score for the pre-knowledge results was 0.62 or 62% correct, while after watching the film, it improved to 0.70 or 70% correct.

Using data from the paired sample t-test, we calculated Cohen's d or effect size of the intervention. The effect size was highest (0.47) for knowledge questions; the effect size was lowest (0.20) for behavior and 0.25 for attitude (Table 2-5). The criteria used for evaluating effect was 0.2 equals small, 0.5 equals medium, and 0.8 equals a large effect size (Cohen, 1969).

Kraft (2018) suggested that a small effect size by Cohen's system was often a large effect size in the context of field-based education intervention. Cohen's d effect size for using the documentary *Switch* as an intervention indicates it has the potential to change students' attitude, behavior, and improve energy knowledge over a 2-3 day learning activity. This research supports using *Switch* as an inexpensive, scalable teaching tool to introduce energy and improve energy literacy.

Effect Size				
Assessment	**N**	**Mean**	**Std. Deviation**	**Cohen's d**
Attitude	389	0.094	0.371	0.25
Behavior	388	0.093	0.458	0.20
Knowledge	389	0.072	0.153	0.47

Table 2-5: Paired Sample T-Test- Cohen's d

Discussion

This research evaluated the effectiveness of *Switch* as a teaching tool to improve energy literacy in high school and university students. The results showed the film affected students' attitude about energy, their energy behavior, and their knowledge of energy and related issues. The strongest effect size was with knowledge questions answered in the documentary. The 0.47 effect size indicates the use of the film over a two-day class is effective for increasing student knowledge and enhancing their attitude toward and acceptance of changes needed to move toward a more sustainable energy future, as measured by post-test with our instrument.

Energy to power the global economy and the resources necessary to build the infrastructure to meet the world's expanding energy demand will rely on geoscientists to locate the raw materials, identify the best locations for wind and solar energy, and evaluate the environmental impact of these choices. The film introduces students to the work of scientists and the diverse field of energy, and how different places in the world are meeting these challenges. Viewing the film might inspire students pursue a career in the field of energy.

Switch is a non-partisan, objective, entertaining documentary that, if structured as an active class learning experience, offers the potential to improve students' energy literacy and inspire and motivate students to learn more. The film provides an effective teaching tool for middle school, high school, and university teachers to introduce the main types of energy resources, the effectiveness of energy efficiency and energy conservation, and the challenges of future energy reduction.

Limitations

The limitations of this study are that the film is the starting point for a unit on energy, but does not attempt to go into depth on energy resources or all energy related topics. Student learning was not supported by any other ancillary activities before, during, or after the film, and no online material to support the film was provided. Teacher-student engagement before, during, and after the film was not requirement or included for this assessment, the assessment strictly tested the film by itself.

The participants are not demographically very diverse, with a number of states not represented, and we did not collect socio-economic status of students. Some students did not correctly follow instructions for copying the link to the post-assessment with less than 50% of the participants creating and using the random ID to take the post-assessment. This reduced valid pre- and post-assessments for the paired sample t-test to only 389 students.

We did not collect data on students' previous education in the sciences, which limits the interpretation of these results. We only evaluated students' responses immediately following the film and therefore do not know if they retained this knowledge or if the changes in attitude and behavior persist into the future. Another limitation is the time constraint for this type of assessment, which needed to be short enough to be taken by students in 15-20 minutes or less.

Future Directions

It would be useful to reach a wider, more diverse group of students and make the pre to post transition more effective by increasing the number of matching pre- and post-assessments. Testing *Switch* as an effective introduction to the energy unit in the Advanced Placement Environmental Science (APES) could be compared to results from other lower-level high school courses to determine whether the effect size of this teaching tool is the same for a variety of students at different levels of education.

It would be useful to investigate what approaches could be used in the production of an objective, non-partisan documentary film to enhance critical thinking and the learning experience of viewers. Film has the power to play to emotions and sway opinion, but that power can also be used to manipulate public understanding in a way that appears to be advancing knowledge, but is factually inaccurate. An example of this type of energy film is *Gasland*, which created strong anti-fracking sentiment in the public, even though many of the implied facts and connections were later shown to be misleading and inaccurate (references). Investigating the type of film-based tools that educators can use to help develop critical thinking skills in students would be very powerful.

Conclusion

Energy literacy surveys over the years have consistently identified Americans' with a low energy IQ. This study tested the effectiveness of using the film *Switch* as a teaching tool to improve energy literacy. The assessment tool used to evaluate the effectiveness of the film was shown to be internally consistent, and a factor analysis

identified three reliable components for the pre-and post-attitude section of the assessment. Independent sample t-test demonstrated some gender differences between post-attitude responses and pre-behavior responses, but no statistically significant differences in knowledge between male and female students. Paired sample t-tests show uni-dimensional improvement for attitude, behavior, and knowledge, respectively. This research shows that although *Switch* was not created with a classroom audience in mind, it is nonetheless an effective teaching tool for improving energy literacy with significant (0.47) effect size, and it is inexpensive, scalable. With a classroom audience in mind, future documentary films may be able to improve further on the impact of film to improve non-partisan, objective education.

Appendix A: SEA Energy Literacy Assessment

Introduction:

Thank you for your interest in participating in this energy literacy research project. Our goal with this research is to help improve the way we teach the next generation to understand energy resources (natural gas, solar, oil, wind, nuclear, etc…), usage, energy conservation and how to meet the expanding future energy demand around the globe.

We believe non-partisan science-based films can help change the conversation and improve energy literacy in an inspiring, motivating, and entertaining way. Your responses are very important to evaluate student energy knowledge, attitude, and behavior, and the effectiveness of using the film *Switch* to improving energy literacy. Your answers will help us benchmark current student knowledge on this topic, so we can create better and more engaging curriculum moving forward.

With energy!
Dr. Scott Tinker and Harry Lynch

SECTION I: Student Information

Q1 Gender

- ○ Male (1)
- ○ Female (2)

Q2 Which country did you go to high school? _____

Q3 Which state did you go to high school? _____

Q4 What is your year of birth? _____

SECTION II: Opinions about Energy. There is no right or wrong answer.

Q5 Please indicate your opinions about energy.

	Strongly agree (5)	Somewhat agree (4)	Neither agree nor disagree (3)	Somewhat disagree (2)	Strongly disagree (1)
I have an above-average knowledge about energy production, consumption, and conservation (1).	○	○	○	○	○
Energy conservation and efficiency should be a part of a balanced education (2).	○	○	○	○	○
New technology will solve our future energy problems (3).	○	○	○	○	○
Addressing climate change is more important than addressing global poverty (4).	○	○	○	○	○
We should develop renewable energy, regardless of economic and environmental costs (5).	○	○	○	○	○
My personal use of energy does not make a difference in the grand scheme of things (6)	○	○	○	○	○
I don't worry about turning off lights or computers in the classroom because the school pays for the electricity (7).	○	○	○	○	○
The fastest way to address climate change is to convert from fossil fuels to renewable energy (8).	○	○	○	○	○
Governments should develop standards for gas mileage of cars and efficiency of appliances [refrigerators, dryers] (9).	○	○	○	○	○
All electrical appliances should have a label that shows the resources used in making them, their energy requirements, and average operating costs (10).	○	○	○	○	○
More wind farms should be built to generate electricity, even if they are located in scenic valleys or hills, farm or ranch lands, lakes or oceans (11).	○	○	○	○	○

Present day climate change is caused by human activity (12).	○	○	○	○	○
Renewable forms of energy are good (13).	○	○	○	○	○
Fossil fuels are bad (14).	○	○	○	○	○
Nuclear power is bad (15).	○	○	○	○	○

SECTION III: Energy Behavior. There is no right or wrong answer.

Q6 Please indicate your energy behavior.

	Always (5)	Quite frequently (4)	Sometimes (3)	Not very often (2)	Never (1)
I attempt to save water (1).	○	○	○	○	○
I will walk or bike short distances, instead of driving a car (2).	○	○	○	○	○
I turn off lights when leaving a room (3).	○	○	○	○	○
I turn off my computer when I am not using it (4).	○	○	○	○	○
I adjust the temperature of my air conditioner and heater to save energy (5)	○	○	○	○	○
I buy energy efficient LED light bulbs (6).	○	○	○	○	○
I drive an energy efficient car (7).	○	○	○	○	○

I limit my cell phone and tablet use (8).	○	○	○	○	○
I buy non-GMO, organic food (9).	○	○	○	○	○

SECTION IV: Energy Knowledge. Choose the best answer.

Q7 Which energy source supplies the majority of transportation fuel?

- ○ Petroleum (1)
- ○ Natural gas (2)
- ○ Coal (3)
- ○ Renewables (4)

Q8 Which of these is NOT a benefit of using coal to generate electricity throughout the world?

- ○ Affordable (1)
- ○ Environmentally sustainable (2)
- ○ Available (3)
- ○ Reliable (4)

Q9 Which is NOT an advantage of using gasoline in transportation?

- ○ Dense form of energy (1)
- ○ Affordable on a per mile basis (2)
- ○ Reliable access and options for refueling (3)
- ○ Carbon dioxide emissions (4)

Q10 Which two nations will continue to dramatically increase vehicles purchased in the near future?

- ○ China and United States (1)
- ○ India and Brazil (2)
- ○ China and India (3)
- ○ Brazil and Mexico (4)

Q11 Which sector of the United States consumes the most energy?

- ○ Residential (1)
- ○ Commercial (2)
- ○ Industrial (3)
- ○ Transportation (4)

Q12 Which has the greatest effect on the energy efficiency of your car?

- ○ Weight of car (1)
- ○ Type of gasoline (2)
- ○ Cleanliness of oil filter (3)
- ○ Air pressure in tires (4)

Q13 An incandescent light bulb converts 10% of the energy into light and 90% into which form of energy?

- ○ Mechanical (1)
- ○ Potential (2)
- ○ Thermal (3)
- ○ Chemical (4)

Q14 As the thermal energy in a substance increases _____

- ○ mass increases. (1)
- ○ molecular motion remains the same. (2)
- ○ molecular motion decreases. (3)
- ○ molecular motion increases. (4)

Q15 Which activity in a typical American home uses the most energy?

- ○ Lighting rooms (1)
- ○ Heating and cooling rooms (2)
- ○ Heating water (3)
- ○ Refrigerating food (4)

Q16 What is NOT an environmental downside of electric cars?

- ○ Battery disposal (1)
- ○ Electricity generation for charging (2)
- ○ Mining of metals (3)
- ○ Lower tailpipe emissions (4)

Q17 A primary advantage of nuclear power over coal or natural gas for electricity is

- ○ no direct carbon dioxide emissions (1)
- ○ no cooling water (2)
- ○ no mining (3)
- ○ no waste products (4)

Q18 Which country consumes the most energy?

- ○ U. S. (1)
- ○ Russia (2)
- ○ China (3)
- ○ India (4)

Q19 The original source of energy for almost all living things is _____

- ○ Water (1)
- ○ Sun (2)
- ○ Plant life (3)
- ○ Soil (4)

Q20 It is currently not possible to _____

- ○ build a machine that produces more energy than it uses (1)
- ○ convert chemical energy to heat energy (2)
- ○ use ethanol to power an automobile (3)
- ○ save energy by reducing, reusing and recycling products (4)

Q21 Which resource provides about 85% of the energy used in developed countries?

- ○ Biomass (wood, waste, plants, alcohol fuels) (1)
- ○ Hydropower (2)
- ○ Fossil fuels (3)
- ○ Nuclear (4)

Q22 All major economies to date have built their electricity resources using what primary fuel?

- ○ Oil (1)
- ○ Coal (2)
- ○ Uranium and thorium (nuclear) (3)
- ○ Wind and solar (4)

Q23 Which uses the least energy in the average American home in one year?

- ○ Refrigerating food and beverages (1)
- ○ Washing and drying clothing (2)
- ○ Heating and cooling rooms (3)
- ○ Lighting the home (4)

Q24 Which of the following correctly describes how radioactive waste from nuclear power plants is currently managed in the United States?

- ○ It is buried deep underground and left there (1)
- ○ It is stored on-site at the nuclear power plant (2)
- ○ It is burned (3)
- ○ There is no waste from nuclear power plants (4)

Q25 Select the choice that makes the following statement FALSE: Renewable energy resources like wind and solar impact human health and the environment because _____

- ○ need a lot of land to capture a small amount of energy (1)
- ○ require disposal of blades and panels in landfill (2)
- ○ depend upon redundant back-up systems like chemical batteries and power plants (3)
- ○ have emissions at the source (4)

Q26 France has the cheapest price for electricity in Europe with a minimal carbon dioxide footprint, because they use _____ as their main energy source for electricity.

- ○ Coal (1)
- ○ Nuclear (2)
- ○ Solar (3)
- ○ Hydroelectric (4)

Q27 Which of following statements is TRUE about using fossil fuels for electricity and transportation.

- ○ increases carbon dioxide gases in the atmosphere (1)
- ○ does not affect local air quality (2)
- ○ are very low energy density (3)
- ○ do not have good distribution networks (4)

Q28 The most effective way to reducing our future energy demand is

- ○ discovery of new sources. (1)
- ○ renewable energy. (2)
- ○ energy conservation. (3)
- ○ nuclear power. (4)

SECTION V: Please provide answers to the following questions.

Q29 Which one thing has contributed the most to your understanding of energy?

- ○ Middle and High School Science classes (1)
- ○ AP Environmental Science (2)
- ○ Internet (3)
- ○ Film (4)
- ○ Family and friends (5)
- ○ Books and Magazines (6)
- ○ Other (7) _____

Q30 I have watched a film related to energy that impacted my behavior.

- ○ Yes (1)
- ○ Maybe (2)
- ○ No (3)

Q31 If "Yes" to Question 7, then what was the film?

_____

_____

_____

_____

_____

Q32 What was your most important take away from the film?

_____

_____

_____

_____

_____

SECTION VI: Electricity Generation in the U.S.

Q33 In the United States, what percentage of electricity is generated by each of the following fuel sources? Predict your percentage of electricity for each energy source to a sum of 100%.

Hydropower: _____ (1)

Natural gas: _____ (2)

Nuclear: _____ (3)

Oil: _____ (4)

Coal: _____ (5)

Renewables: _____ (6)

Other: _____ (7)

Total: = **100%**

SECTION V: Only for Pre-Assessment

Q34 Copy and Save Link for Post-Assessment Survey

https://utexas.qualtrics.com/jfe/form/SV_d4mxlfN1LjcwsQt?RandomID=${e://Field/RandomID}

Appendix B: SEA Educator Survey

Introduction:

Thank you for being a *Switch* subscriber! We are developing easy-to-use, film-based content that stimulates dialog on the future of energy in a classroom setting for Educators/Students. This content is aligned with the Energy Resources and Consumption section of the AP Environmental Science Course.

In order to fine tune this effort, we need your input. Would you be willing to help us by completing our *Switch* Energy Alliance (SEA) Educator Survey? Your insight and opinions are key to making this research valuable to both teachers and students as we craft the curriculum to accompany our film-based content. Please complete the very brief SEA Educator Survey to help us improve our website and other materials for educators.

If you have any questions or need additional information, please contact Jim Corboy at: jjcorboy@utexas.edu

With energy! Dr. Scott Tinker and Harry Lynch

Teacher Information:

Q1 Last Name: _____

Q2 First Name: _____

Q3 My email address is: _____

Q4 In which country do you currently reside? _____

Q5 In which state do you currently teach/reside? _____

Q6 Grade levels I teach (multiple answers):

- ○ K-2 or early childhood (1)
- ○ 3rd-5th (2)
- ○ 6th-8th (3)
- ○ High School (4)
- ○ Undergraduate (5)
- ○ Post-graduate (6)

Q7 Subjects I teach (multiple answers):

- ○ General Science (1)
- ○ Social Studies (2)
- ○ Physics (3)
- ○ Environmental Science (4)
- ○ Chemistry (5)
- ○ Integrated Physical Science (6)
- ○ Earth Science (7)
- ○ Other (8) _____

Q8 Do you use Switch Energy Project or Switch Energy Alliance (SEA) materials as a graded component of your course?

- ○ Yes (1)
- ○ No (2)
- ○ Not applicable (3)

Q9 Do you use SEA materials as a supplemental (ungraded) component of your course?

- ○ Yes (1)
- ○ No (2)
- ○ Not applicable (3)

Q10 Is this course that you are using SEA materials, required or an elective?

- ○ Required (1)
- ○ Elective (2)
- ○ Not applicable (3)

Q11 Are there published standards for your course?

- ○ Yes (1)
- ○ No (2)
- ○ Not applicable (3)

Q12 Which standards or topics from your curriculum are covered by the SEA materials?

_____

_____

_____

_____

_____

Q13 How often do you use SEA materials in your course?

- ○ once a year (1)
- ○ once a semester (2)
- ○ multiple times a semester (3)
- ○ other (4) _____
- ○ Not applicable (5)

Q14 What SEA materials have you used (multiple answers)?

- ○ full feature film (1)
- ○ short energy labs videos (2)
- ○ energy primers (3)
- ○ energy experts (4)
- ○ other (5) _____
- ○ Not applicable (6)

Q15 How useful are SEA materials for teaching about energy?

- ○ Extremely useful (1)
- ○ Very useful (2)
- ○ Moderately useful (3)
- ○ Slightly useful (4)
- ○ Not at all useful (5)

Q16 How could we make the SEA videos more useful for teaching about energy? (multiple answers)

- ○ more detailed teacher guides (1)
- ○ accompanying lesson plans (2)
- ○ homework activities or exercises (3)
- ○ supporting written content to videos (4)
- ○ additional assessment resources (5)
- ○ set of questions to accompany each video (6)
- ○ other (describe in box) (7) _____

Q17 What are other standards or topics that would be useful for SEA video content materials to cover?

_____

_____

_____

_____

Q18 Have you created curriculum to use with SEA materials?

- ○ Yes (1)
- ○ No (2)

Q19 Would you be willing to share your SEA curriculum?

- ○ Yes (1)
- ○ No (2)
- ○ Not applicable (3)

Q20 Would you be interested in using our assessment tools along with the Switch film to evaluate the effect of our film on student energy literacy learning? Reward for participating will be early access to our new upcoming film on energy poverty including tickets to the premiere.

- ○ Yes (1)
- ○ No (2)

Q21 Would you be interested in starting a Switch Energy Club Chapter at your school?

- ○ Yes (1)
- ○ No (2)

Q22 How did you first find out about the Switch Energy Alliance?

- ○ Watched the film (1)
- ○ Conference (2)
- ○ Word of mouth (3)
- ○ Internet search (4)
- ○ Dr. Tinker talk (5)
- ○ Other (6) _____

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